Market Analysis
Program (MAP)

Cross-Industry Markets 1988-1993

Engineering and Scientific Sector

INPUT®

1280 Villa Street, Mountain View, CA 94041 (415) 961-3300

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CROSS-INDUSTRY MARKETS 1988-1993

ENGINEERING AND SCIENTIFIC SECTOR

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Issues, Trends, and Events

A Definitions

Computer-aided engineering (CAE) and computer-aided design (CAD) are the major components of the applications that are covered in the engineering and scientific market. Sometimes the terms CAE and CAD are used interchangeably because they both refer to design automation tools. However, there are important differences between the two:

CAE systems are used at the front-end, where products are conceived. They are used by engineers to automate the analysis and simulation of the design. In analysis and simulation, a mathematical or software model of the design is created and tested under various conditions. The results of the tests show what a physical model would do under the same conditions.

On the other hand, CAD systems are used to draw and analyze physical structures. They are typically employed at the end of the product development process, where they are used to convert engineers' designs into production drawings.

CAD includes a wide range of applications:

- Mechanical design and drafting that include wireframe analysis, surface design, and solid modeling
- Electronic design that includes circuit analysis, schematic capture, schematic design-rule checking, and integrated-circuit layout
- Civil engineering, including architecture, engineering, and construction (AEC) applications that encompass plant design, piping design and analysis, building design and management, mapping, and site engineering

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Approximately 17 percent of the total CAE/CAD turnkey systems are included in the engineering and scientific segment forecasts. The remainder is included in the discrete manufacturing, process manufacturing, utilities, transportation, federal government, and other sectors.

Likewise, CAM (computer-aided manufacturing) applications are excluded from the analysis and forecasts in the engineering and scientific sector. User expenditures for CAM applications are included in the discrete manufacturing sector.

B

Introduction

The CAE/CAD market is characterized by the influx of microcomputer- and workstation-based products into what has been a minicomputer- and mainframe-dominated market. PC- and workstation-based systems have hurt sales of high-end systems. The major trends in the CAE/CAD industry are the following:

- Move toward open architecture or industry-standard platforms
- High level of consolidation marked by numerous vendor acquisitions and a great number of marketing alliances
- Emergence of systems to integrate machanical design, engineering, and shop floor manufacturing systems
- Integration of data management and computing systems. An effective data base management environment is necessary for the integration of a multivendor information system
- Communications across disparate workstations and computer systems from multiple vendors. In order to address these communication problems, vendors are making major shifts in their workstation offerings toward systems based on emerging industry standards
- Distribution solutions in a hierarchical setting. The promise of a hierarchy of computing systems is that data management and archiving functions are performed at the host level and the interactive data management and design applications at the workstation level.
- Back-end processors at the departmental level
- Move toward solid modeling and three-dimensional capabilities
- Introduction of more intelligence through the incorporation of expert systems
- Move toward component systems. Companies that already have computers installed are reluctant to buy integrated CAE/CAE systems

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that may duplicate what they already own. Instead, they are likely to want separate components such as software and graphics workstations that they can connect to their existing systems.

Most large industrial corporations have operated for years in an environment where design and manufacturing communicate infrequently, if at all. Many companies have come to realize the disadvantages of this sequential approach to product development and have realized the benefits of doing more analysis earlier in the design cycle. The prospects of reducing prototyping costs, fewer design changes, faster time to market, and increased product quality and reliability are attractive to management. Companies have become aware that they can improve both the product and the process by doing more initial design analysis. Getting it right, and getting it right the first time, saves money downstream. As a result, manufacturers are implementing systems that can effectively mesh the design and manufacturing processes.

One problem that companies face when trying to integrate the design, manufacturing, and related functions is the problem of incompatibility. Over the years, large users have installed systems from many vendors. Most of these systems are based on the vendors' proprietary architectures, thus making integration difficult to achieve.

Companies have tried to address this issue by establishing corporate standards. For example, General Motors has formed a strategic partnership with two CAD/CAM vendors—McDonnell Douglas Manufacturing and Engineering Systems and Cadam—to develop standards-based applications for automotive design. GM's move was motivated by growing data-exchange problems among its 22,000 CAD/CAM systems that originated from more than two dozen vendors.

The shortage of engineers and scientists in the U.S. is well known. Universities and research institutions facing a critical shortage are resorting to foreign brain power. The shortage of engineers and scientists is growing and is threatening the competitveness of U.S. corporations.

A study by one large corporation has predicted a shortfall of 400,000 engineers, mathematicians, and scientists by the year 2000.

C
Mechanical Engineering

CAE/CAD applications for mechanical engineering have gained importance as these have become easier to use and more integrated with other computer-aided technologies applied to functions such as manufacturing. Analyses that were once performed after a prototype of a product was built are now often done when a computer-generated product design is complete, before prototyping.

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- Users are engineering analysis specialists, design engineers, and manufacturing engineers.
- Users' concerns include better integration of CAD and CAE processes, and greater analysis capabilities in the design stage.
- Benefits of using mechanical engineering CAE/CAD systems are reduced prototyping costs, fewer design changes, faster time to market, and increased product quality and reliability.

D

Electrical/Electronic Engineering

The need for CAD and CAE tools in electronic design resulted from the increasing complexity of large-scale integrated circuits and the electronic systems incorporating such components. This increasing design complexity has significantly lengthened the product development cycle while, at the same time, more competition in the electronics industry has shortened product life cycles.

The primary user benefits of CAE/CAD systems are in producing products less expensively and, more importantly, developing them faster to take advantage of market windows.

CAE is used to improve the quality of design by simulating operational performance and by reducing the turnaround time for various phases of electronics engineering, including defining overall system architecture, logic circuit layout, design-rule checking, and timing simulation.

This integration implies that there will be significant links between the design function and the production function, and links to postproduction issues such as product testing and field service. Engineers want the design to go smoothly from CAD to CAE and then to CAM in a fully integrated system.

The integrated-circuit designers were the initial purchasers of CAE tools. The trend is toward system design rather than chip design. CAE tools will be more gradually adopted by systems designers. The adoption will be accompanied by evolutionary changes in the characteristics of CAE tools and suppliers. Systems designers will require tools that are easier to learn and use and that address a broader range of electronic design applications. It takes a long time, even for a sophisticated circuit designer, to learn how to use new systems.

E

Civil Engineering

civil engineering for the design of structures. FEA treats a continuous structure as if it were made up of many individual blocks or "finite elements." These elements are assumed to be connected to each other in simple geometric shapes. The finite-element method computes stresses at specific points, or nodes, where the structural elements are connected.

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Using this technique, the behavior of complex shapes such as bridges can be studied. (Note: FEA is used in other areas as well—for example, in the design of airplane wings and automobile fenders.)

The computational requirements of FEA are enormous. Speed is the commodity FEA deals in. FEA compacts the time it takes to test designs. FEA has gained wider acceptance due to the dramatic improvements in hardware performance.

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II

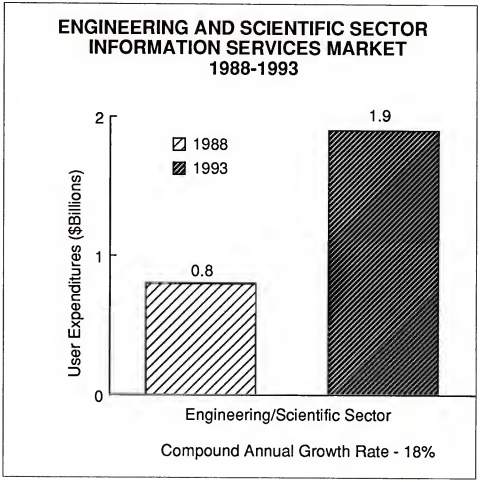
Market Forecasts

A

Introduction

User expenditures for cross-industry engineering and scientific applications will grow 18 percent anually to reach $1.9 billion in 1993, as shown in Exhibit II-1.

EXHIBIT II-1



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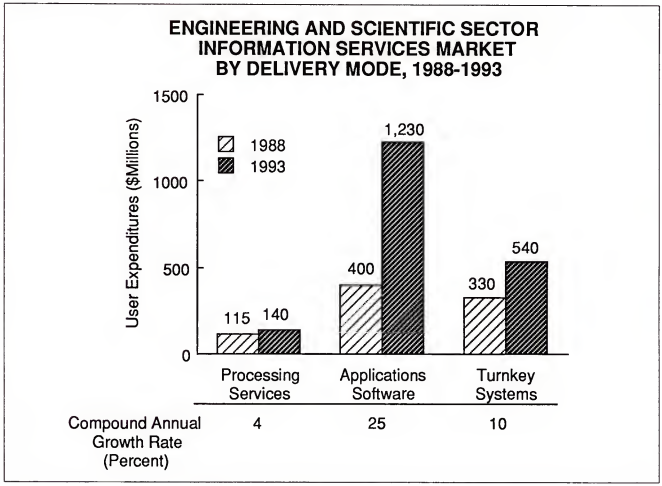
Forecasts for user expenditures by delivery mode are shown in Exhibit II-2. Applications software products will show the most growth, at an annual rate of 25 percent.

Appendix ES-A contains the forecast data base for each year, 1987-1993, by delivery mode.

EXHIBIT II-2



B

Processing/Network Services

Processing and network services will show the least growth among delivery modes. These services will exhibit an annual growth rate of 4 percent.

Users of processing services are large industries, universities, and research organizations. Although processing services is perceived to be a declining market, there is still a demand in some areas, such as supercomputer processing services, as described in the example below.

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- The Alabama Supercomputer Authority was formed to implement a supercomputer system and a data communications network to be used primarily by universities, government departments, and industries within the state. The supercomputer network will be used for conducting research in a number of areas, including superconductivity and simulation exercises.

Market growth is negatively influenced by users who move data processing in-house and thus alleviate the need for processing services.

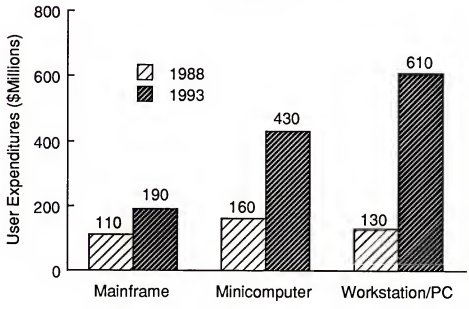
The workstation has emerged as an attractive platform for engineering and scientific applications in recent years. The use of workstations stimulates the turnkey systems and applications software markets at the expense of processing services.

C
Software Products

As shown in Exhibit II-3, applications software products will exhibit strong growth with the workstation/PC subsector showing the greatest annual growth of 36 percent.

EXHIBIT II-3

ENGINEERING AND SCIENTIFIC SECTOR APPLICATIONS SOFTWARE MARKET 1988-1993



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The market for workstation/PC software products is propelled by the strong growth of workstations and personal computers, coupled with the availability of products with improved functionality.

The workstation/PC subsector will also benefit from the unbundling of software from turnkey systems vendors. Because vendors would then lose the margins associated with hardware, vendors have been extremely reluctant to unbundle their systems and to offer software only. Hardware is roughly 50 percent of the total cost of a system and, in addition to hardware revenues, vendors benefit from service contracts. But unbundling is becoming a reality as customers, particularly large users, pressure vendors to unbundle.

D
Turnkey Systems

The computer hardware environment is characterized by rapid technological advances. Product life cycles are decreasing, and competition is fierce, especially in the workstation market.

The workstation is characterized by high-speed color graphics and the ability to run complex programs. Both capacities make intense use of local CPU resources, while tapping shared resources via networking. Technological developments have blurred the distinction between workstations and high-end PCs. Further, the prices of workstations have declined to affordable levels for many users.

The growth of turnkey systems is aided by numerous factors, including significant advances in price/performance of systems, low current penetration, a shift from "mainframe/terminal access" systems to standalone systems associated with the acceptance and increased use of workstations as hardware platforms, and the availability of systems based on industry standards.

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Competitive Developments

A Introduction

The engineering and scientific marketplace is characterized by intense competition, particularly in the turnkey systems area, and industry consolidation, as evidenced by the numerous acquisitions and strategic alliances.

Among hardware platforms, the advances in the workstation arena are of particular interest since workstations offer an attractive platform for developing engineering and scientific applications. Although Sun Microsystems and Apollo Computer specialize in workstation hardware, they will have to contend with increasing competition from DEC, IBM, and Hewlett-Packard. (Note: Hewlett-Packard has recently acquired Apollo Computer.)

There are four major CAE/CAD workstation platforms:

- UNIX workstation (Sun, Apollo, etc.)
- DEC MicroVAX
- IBM workstation (RT PC)
- IBM PS/2 series

IBM's Personal System/2 series of personal computers marks a new front in the workstation/PC arena. These computers offer good graphics, considerable processing power, and large memories.

INPUT feels that a fifth hardware platform will emerge around Apple computers as the company now has the hardware (Macintosh II) for engineering applications. Apple will establish a strong presence in the market as established vendors port their software to Apple hardware.

The CAE/CAD market is characterized by intense merger and acquisition activities, the two most significant of which are perhaps the acquisition of Computervision Corporation (Bedford, MA) by Prime Computer, Inc. (Natick, MA), and the acquisition of Apollo Computer Inc. (Chelmsford, MA) by Hewlett-Packard Company (Palo Alto, CA).

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In January 1988 Prime acquired Computervision for $433 million after a month-long struggle in what was described as a hostile takeover. Further, in October 1988 Prime announced an agreement with General Electric to acquire the latter's Calma Company. These acquisitions make Prime a leading vendor in the CAE/CAD market. (See Prime vendor profile.)

In April 1989, Hewlett-Packard entered into an agreement with Apollo Computer to acquire the company for $476 million. The agreement marks a departure in policy for Hewlett-Packard, which has generally avoided large acquisitions.

The major acquisitions in 1988 are shown in Exhibit III-1.

In October 1988 Silvar-Lisco (Menlo Park, CA), a developer of software for the design of integrated circuits, said that it would explore the possible sale of the company or a merger with another firm. The company stated, "The potential of Silvar-Lisco is not reflected in our company's current stock price."

The market forces facing CAE vendors are the following:

- Users are demanding easier-to-use systems that cost less
- Established CAD/CAM vendors and computer companies are attracted to the CAE market
- IBM and AT&T, with their own advanced internal CAE tools, could each become a major force in the market

It takes a major investment of both time and resources to successfully penetrate this market. The software involved is very complex and, as Hewlett-Packard and Tektronix (vendors that tried to establish a presence in the CAE market) have discovered, more difficult and time consuming than anticipated.

The CAE market for electronics applications used to be dominated by three vendors: Daisy Systems, Mentor Graphics, and Valid Logic. Whereas Daisy and Valid chose to develop both hardware and software, Mentor decided to focus on software only, using workstations supplied from Apollo. Mentor's strategy seems to have paid off as the user community moved toward products based on industry standards. While Daisy and Valid have risen and fallen (both lost money in 1986 and 1987), Mentor has grown steadily and has established itself as the leading electronics CAE vendor. Daisy and Valid have since ported their software to industry-standard platforms, and both have returned to profitability (see vendor profiles).

The leading vendors in the engineering and scientific sector are shown in Exhibit III-2.

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EXHIBIT III-1

SIGNIFICANT MERGERS AND ACQUISITIONS IN THE ENGINEERING AND SCIENTIFIC SECTOR

Month	Company	Acquired by	Comments
Jan 88	Computervision	Prime	Hostile takeover
Mar 88	CASE Division, Textronix	Mentor Graphics	
Apr 88	IC CAD Business, Calma	Valid Logic	
Apr 88	Xanadu Operating Company	Autodesk	Autodesk acquired 80% equity interest
Jun 88	Contour Design Systems	Mentor Graphics	
Jun 88	American Information Exchange	Autodesk	Autodesk acquired majority interest
Oct 88	Integrated Measurement Systems	Valid Logic	
Nov 88	HHB	Cadnetix	
Nov 88	Simucad	Cadnetix	
Dec 88	Cadnetix	Daisy	
89	Calma	Prime	
Apr 89	Apollo	Hewlett-Packard	

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EXHIBIT III-2

SELECTED LEADING VENDORS IN THE ENGINEERING AND SCIENTIFIC SECTOR, 1987

	Revenue ($Millions)				Market Share (Percent)
	Proc. Svc.	Appl SW	Turnkey Systems	Total	
Prime/Computervision		15	72	87	12
Intergraph		6	60	66	9
Autodesk		50	-	50	7
Calma		10	16	26	4
Schlumberger CAD/CAM		10	14	24	3
Mentor Graphics		-	23	23	3
MacNeal-Schwendler		17	-	17	2
Gerber Scientific		-	15	15	2
Daisy		-	10	10	1
Auto-trol		-	9	9	1
Valid Logic		-	8	8	1
Hewlett-Packard		6	-	6	1
Subtotal	0	114 (37%)	227 (73%)	341	46
All Other Vendors	110 (100%)	196 (63%)	83 (27%)	389	54
TOTAL	110	310	310	730	100

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B

Vendor Profiles

1. AUTO-TROL TECHNOLOGY CORPORATION (12500 North Washington Street, Denver, Colorado, 80233)

a. Products/Services

Auto-trol Technology Corporation develops, markets, and supports distributed graphics solutions for CAE/CAD/CAM applications, technical publishing, and telecommunications.

Series 5000 is a graphics system on which Auto-trol's range of building design, industrial plant design, process plant design, and technical publishing application packages are built.

Series 7000 is a mechanical product development tool that provides three-dimensional modeling capabilities.

Tech Illustrator applications software consists of drawing and annotation tools designed specifically for the professional technical illustrator.

VECTORPIPE is Auto-trol's piping design, analysis, and drawing creation system.

EMPRESS/32 is a general-purpose relational data base management system.

Auto-trol also offers numerous other software products for architecture, engineering, and construction (AEC), technical publishing, and mechanical design and manufacturing applications.

b. Markets Served

Auto-trol's customers include petroleum and chemical companies; architectural and engineering firms; construction contractors; aerospace companies; federal, state, and local governments; retail merchandisers; public utilities; and manufacturers.

c. Company Strategy

Auto-trol follows a philosophy of developing products based on industry standards. The company's systems are developed with standard interfaces (both hardware and software) so its customers can incorporate third-party or jointly developed applications into their Auto-trol system to meet their specialized needs. Since 1982 the company has positioned itself as a supplier of 32-bit engineering workstations with turnkey expertise in systems integration within a distributed data processing environment.

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d. Recent Activities

In December 1987 Auto-trol released Facility Layout/Industrial (FL/I), software that combines graphics with a relational data base management system. FL/I allows large manufacturing companies to evaluate design alternatives for improving manufacturing efficiency.

In July 1988 Auto-trol announced an OEM agreement with Sun Microsystems, Inc. (Mountain View, CA) under which Auto-trol will market its electronic publishing systems (EPS) on the Sun-3, Sun-4, and Sun 386i workstations.

e. Future Directions

Auto-trol plans ongoing improvements to its graphics systems, applications software, and communications products.

2. AUTODESK, INC. (2320 Marinship Way, Sausalito, California, 94965)

a. Products/Services

Autodesk, Inc. designs, develops, markets, and supports a family of computer-aided design and drafting software products for microcomputers and 32-bit workstations.

Autodesk's flagship product, AutoCAD®, was introduced in 1982 and has since been enhanced through a series of upgrades.

- AutoCAD operates on most major personal computers and workstations.

- AutoCAD automates the design and drafting process by enabling users to interactively create, store, and edit a variety of drawings. This drawing information may be exchanged with other applications software, data bases, and mainframe CAD systems. Enhancements to AutoCAD have added new capabilities, including increased drawing speed, automatic dimensioning, three-dimensional visualization and hidden line removal, and the capability of controlling the program through functions written in the LISP programming language.

- Over 150,000 units of AutoCAD have been sold.

AutoSketch is a low-cost, full-function drawing program for use on microcomputers.

AutoCAD AEC® Architectural, formerly known as AE/CADD, is an integrated architectural design and drafting sytem for use with AutoCAD.

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AutoCAD AEC® Mechanical enables engineers to design and edit diagrams for engineering applications and provides a library of industry standard symbols used in engineering drawings.

AutoShade™ transforms AutoCAD drawings into three-dimensional images showing perspective, lighting, and reflection.

AutoFlix™ is a software utility for animating two- and three-dimensional images produced by AutoCAD, AutoShade, and AutoSketch.

b. Markets Served

Autodesk's products generally are designed for broad market distribution to users without specialized CAD training. Typical users include mechanical, structural, and electrical engineers; architects; facilities planners; technical illustrators; interior designers; surveyors, electronic system designers; and educators.

c. Company Strategy

Autodesk's strategy in the development of AutoCAD and its other products has been to offer a low-cost, easy-to-use CAD package that runs on virtually all computers supporting the MS-DOS operating system, as well as on certain engineering workstations supporting UNIX or similar operating systems.

Autodesk's products address the market for low-cost CAD software. Accordingly the company has employed mass marketing techniques, such as advertising in trade and business journals. The company has held and plans to continue to hold annual "Expos," which are dedicated trade shows incorporated within a major industry show.

d. Recent Activities

In April 1988 Autodesk acquired an 80-percent equity interest in Xanadu Operating Company (Palo Alto, CA). Xanadu is a developer of the Hypertext System, which stores, manages, and manipulates text and graphical interfaces.

In June 1988 Autodesk announced that it has acquired a majority interest in American Information Exchange Corp. (Palo Alto, CA). American Information Exchange develops software that facilitates information sharing within and between organizations.

e. Future Directions

The company intends to continue to recruit and hire experienced software developers while at the same time considering the acquisition of complementary software technology and products.

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Autodesk's products are mostly used by small companies. The company's intended goal is to expand into the Fortune 1000 market.

3. CALMA COMPANY (501 Sycamore Drive, Milpitas, California, 95035)

a. Products/Services

Calma Company, a General Electric Company (Fairfield, CT), subsidiary that was founded to develop digitizing equipment, offers CAE/CAD/CAM turnkey systems and software products for a variety of applications.

Calma's CAE/CAD/CAM systems have been designed for three distinct application areas: electronics, mechanical products, and AEC.

The company's products run on DEC VAX and MicroVAX II computers, Apollo workstations, and Data General minicomputers. Calma's software can be integrated with hardware as a turnkey system or can be purchased as a standalone software package.

Electronics software available on Calma's systems includes the following:

- GDS II (Graphics Design System) is a programmable graphics system providing drawing, edit and display, and file management functions.
- BOARD Series™ CAE/CAD/CAM tools provide printed circuit board (PCB) designers with an integrated solution—that is, schematic capture, simulation, design verification, and test development capabilities.

Prism/DDM™ is a fully integrated three-dimensional geometric modeling system for mechanical applications.

Dimension III is Calma's three-dimensional interactive graphics system for AEC applications.

b. Markets Served

Calma's systems are used in the electronics, mechanical, architectural, engineering, and construction industries.

c. Recent Activities

In April 1988 Calma sold its integrated-circuit CAD business to Valid Logic Systems (San Jose, CA). With an estimated 2,700 users, Calma's integrated-circuit business had revenue of about $40 million in 1987.

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In October 1988 Prime Computer and General Electric announced an agreement whereby Prime would acquire GE's Calma business and enter into a strategic alliance with GE for the development and purchase of CAD/CAM software. The acquisition was completed in early 1989.

4. DAISY SYSTEMS CORPORATION (700 East Middlefield Road, Mountain View, California, 94043)

a. Products/Services

Daisy Systems Corporation designs, manufactures, markets, and services CAE systems for electronics applications.

Daisy's products are used in the electronic engineering process for design entry, verification, test development, physical layout, and systems integration at the integrated circuit (IC) and system levels.

The LOGICIAN 386 is a high-end workstation optimized for physical layout applications.

The Personal LOGICIAN 386 is a 32-bit desktop workstation.

The Mega LOGICIAN is a general-purpose simulation accelerator supporting Daisy's logic simulation and fault simulation software.

The Physical Modeling System (PMS) allows VLSI (very large scale integration) components, subsystems, PCBs, semicustom and custom circuits to be physically integrated into the verification process, eliminating the need to create separate software models for their simulation.

The Daisy Engineering Environment is an integrated, distributed local-area network that supports all of Daisy's CAE design systems and is a full implementation of the Ethernet local-area network standard.

Daisy offers a broad range of software products, including Daisy Logic Simulator, Daisy Timing Verifier, Analog Design Series, PLD Master, MegaFAULT, GATEMASTER, CHIPMASTER, BOARDMASTER, Mechanical Documentation Program, and STAR Router for electronics CAE applications.

b. Markets Served

Daisy's products are used for electronics applications in a variety of industries, including military/aerospace, semiconductors, computers, telecommunications, and consumer electronics.

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c. Company Strategy

In last year's report INPUT stated, "Once considered a star performer . . . Daisy has fallen far and fast. The company has embarked . . . on a strategy of developing systems based on industry-standard hardware." Daisy's strategy seems to be paying off. The company returned to profitability in the fourth quarter of fiscal 1987, its first profitable quarter since calendar 1985, and has remained profitable through the fourth quarter of fiscal 1988.

In addition, Daisy management attributes its improved performance to cost reductions associated with the reorganization of the company along functional lines. The critical element, however, is the introduction of products based on standard operating environments, including developing products for Sun workstations.

d. Recent Activities

In January 1988 Daisy announced an OEM agreement with Sun Microsystems under which Daisy would provide the SunOS operating system (Sun's version of the UNIX operating system) across Daisy's product line of 80386-based workstations and Sun-4-based servers. Daisy would also offer CAE products on the Sun 386i family of workstations under the label of Advansys Series.

In September 1988 Daisy began shipping its new Advansys Series workstations, coupling Daisy's electronic design software and the Sun 386i workstation.

In August 1988 Daisy announced an OEM licence agreement with Frame Technology Corporation (San Jose, CA) under which Daisy will sell FrameMaker professional publishing software as an option with Daisy's Advansys Series CAE/CAD workstations featuring SunOS operating system.

In September 1988 Daisy made an unsolicited tender offer for Cadnetix Corp. (Boulder, CO). Cadnetix specializes in software used for computerized layout of printed circuit boards (PCBs). Cadnetix decided to fight the hostile takeover bid. Daisy's acquisition efforts have a humorous angle due to the series of acquisitions involved. While Daisy strived to acquire Cadnetix, Cadnetix was in the process of acquiring HHB, Inc. (Mahwah, NJ), which in turn was in the process of acquiring Simucad, Inc. (Menlo Park, CA), leaving the employees of Simucad a little confused. HHB is a developer of CAE software for logic timing and fault simulation, while Simucad is a developer of software for simulating and testing electronic designs. In November 1988 Cadnetix completed the acquisitions of HHB and Simucad, and Daisy has since completed the acquisition of Cadnetix.

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e. Future Directions

INPUT feels cautiously optimistic about Daisy. As mentioned earlier, Daisy has incorporated industry standards into its products and will base its future development around these standards. It is to be seen whether Daisy will regain its former glory and once again become a major player in the electronics CAE market.

5. INTERGRAPH CORPORATION (One Madison Industrial Park, Huntsville, Alabama, 35807-4201)

a. Products/Services

Intergraph Corporation designs, manufactures, markets, and supports interactive computer graphics and data base management systems addressing a variety of CAE/CAD/CAM applications. Intergraph systems combine data processing systems, graphics workstations, and other hardware to operate CAE/CAD/CAM software. The company uses the DEC VAX line of minicomputers and a proprietary series of workstations.

Intergraph's systems are used for a variety of applications: mechanical design, engineering and manufacturing, electronics design and manufacturing, electronic publishing, architectural and engineering design, civil engineering, plant design, electrical design and engineering, land use and resource management, cartography, and energy exploration and production.

Intergraph's high-end systems are network-based and are configured using a combination of the following equipment: DEC VAX minicomputer, File Processor™, communications processors, servers, graphics workstations, special-purpose scanners, photoplotters, and peripherals such as disk drives, plotters, tape drives, terminals, and line printers.

Intergraph's major software products are described in the following paragraphs.

- Interactive Graphics Design Software (IGDS), for the DEC VAX, is basic graphics software that provides the fundamental graphics elements—including creation, maintenance, and display functions—through the graphics workstations. IGDS supports both two- and three-dimensional graphics.

- Data Management and Retrieval System (DMRS), for the DEC VAX, is responsible for attribute (nongraphics) data management on the Intergraph system. DMRS is a logically and functionally complete data base management system.

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- MicroStation and MicroStation 32 are IGDS-compatible software packages that run on Intergraph workstations.

- Intergraph Graphics Environment (IGE) is designed for object-oriented applications on Intergraph workstations.

The company also provides many other software products for graphics and data management applications.

b. Markets Served

Intergraph's products are used by discrete manufacturing, process manufacturing, transportation, utilities, architectural firms, civil engineers, construction companies, and federal, state, and local governments.

c. Company Strategy

Intergraph targets broad industries, as opposed to specific applications or disciplines—leveraging its size in the industry. The company's thrust has always been to tackle the larger problems—time to market, quality of end products, improvements in productivity—that can only be solved by automating more than one phase of a work flow.

Intergraph differs from other CAD/CAM vendors in that the company uses its own workstations (based on the 32-bit CLIPPER microprocessor produced by the Clipper division of Fairchild Semiconductor that Intergraph acquired in October 1987) rather than workstations from vendors such as Sun and Apollo. Intergraph produces its own workstations because the company believes it is more price/performance functional for CAD/CAM design tasks, and also because the company can generate higher gross margins. The company has, however, rewritten its software so that it is compatible with the UNIX operating system, enabling an easy transition to another vendor's workstation, if need be.

d. Recent Activities

In April 1988 Intergraph stated that it would work with AT&T to tune that company's UNIX operating system to run on its CLIPPER family of microprocessors.

e. Future Directions

Intergraph will continue to enhance its broad range of applications, considered to be the broadest and most comprehensive among CAD/CAM vendors.

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6. THE MACNEAL-SCHWENDLER CORPORATION (815 Colorado Boulevard, Los Angeles, California, 90041-1777)

a. Products/Services

The MacNeal-Schwendler Corporation (MSC) develops and markets CAE applications software for use principally by engineers and designers in industry, research laboratories and universities.

MSC's principal product, MSC/NASTRAN, based upon finite element analysis/modeling (FEA/FEM) is a basic analytical tool. The product is used by engineers and designers to analyze products and structures to determine, among other things, their strength, safety, and performance characteristics. MSC/NASTRAN can be used on a wide variety of computers—from supercomputers to mainframes to microcomputer-based workstations.

- MSC/NASTRAN II is a subset of MSC/NASTRAN and runs on DEC's smaller VAX-series minicomputers and Apollo workstations. MSC/NASTRAN II is intended to serve the basic analytic needs of the engineering community in a workstation environment.

MSC follows a policy of leasing rather than selling its software products. The software can be installed on the client's in-house computer or accessed through the company's data center network.

In addition to MSC/NASTRAN, the company offers a broad range of software products described in the table below.

MSGMESH	Input data generation
MSC/ACCESS	Access utility subroutines
MSC/TRANS	Data transfer
MSC/STI-VAMP	Vibration, acoustic, and modal processing
MSC/pal 2	3-D stress and vibration analysis
MSC/cal	3-D steady-state and transient heat transfer analysis
MSC/mod	Model building
MSC/MAGNUM	3-D magnetic field analysis
MSC/MAGNETICS	2-D electromagnetics analysis
MSC/MAGGIE	Version of MSC/MAGNETICS

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b. Markets Served

MSC's products are used in aerospace, automotive, shipbuilding, industrial and office equipment, nuclear engineering, petrochemical industries, architecture, and general engineering.

c. Company Strategy

MSC has in recent years emphasized installation of its products on clients' in-house computers as opposed to data center network use. Data center use, however, continues to be an important source of revenue and a means of introducing new users to MSC/NASTRAN.

d. Recent Activities

In December 1987 MSC acquired CAD COMP, Inc., a subsidiary of A. O. Smith Corporation (Milwaukee, WI). CAD COMP's two primary thrusts are engineering/consulting and developing engineering-oriented software products in the field of electromagnetics analysis.

In January 1988 MSC announced its first FEA package, MSC/pal, for Apple Computer's Macintosh II and Macintosh SE computers.

In April 1988 MSC announced MSC/mod, a graphics modeling program that enables users of FEA to create and edit models of proposed designs and analyze their reactions to stress, vibration, pressure, and temperature without building a physical prototype.

e. Future Directions

MSC plans to expand its product line by developing software for microcomputers.

7. MENTOR GRAPHICS CORPORATION (8500 S.W. Creekside Place, Beaverton, Oregon, 97005-7191)

a. Products/Services

Mentor Graphics Corporation designs, manufactures, markets, and services electronic design automation (EDA) turnkey systems for use in the design and analysis (CAE or computer-aided engineering), physical layout (CAD or computer-aided design), testing (computer-aided test or CAT), documentation (computer-aided publishing or CAP), and packaging (computer-aided electronic packaging or CAEP) of complex integrated circuits (ICs), printed circuit boards (PCBs), and electronic systems.

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Mentor Graphics IDEA Series™ of Engineering Workstations is an all-inclusive term that refers to the company's products. The IDEA Series combines Mentor Graphics' software with Apollo workstations. The products and applications are listed in the table below.

Design	Capture Station®
Design and analysis	Design Station®, Idea Station®, MSPICE™, MSIMON™, Hardware Modeling Library™ QuickSim™/QuickFault™
Physical layout	Board Station®, Gate Station®, Cell Station®, Chip Station®, REMIDI™
Analysis and physical layout acceleration	Compute Engine™
Electronic packaging and analysis	Package Station™

b. Markets Served

Mentor Graphics focuses on the aerospace, computer, semiconductor, telecommunications, and consumer electronics industries.

c. Company Strategy

Mentor Graphics' strategy is to provide an integrated set of productivity tools across a broad price-performance range to support the electronic engineer throughout the entire product development process.

d. Recent Activities

In February 1988 Mentor Graphics announced Package Station™, a product that addresses the needs of the mechanical designer working in electronic systems design.

In March 1988 Mentor Graphics announced the acquisition of the Computer-Aided Software Engineering (CASE) Division and selected CAE technologies from Tektronix, Inc. (Beaverton, OR).

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In May 1988 Mentor Graphics announced the Mentor Graphics Rasterizer, a software tool that accelerates the generation of complex color pictures or "plots" of ICs and PCBs on large-format plotters.

In June 1988 Mentor Graphics acquired Contour Design Systems, Inc. (formerly Acotech, Menlo Park, CA). Contour Design Systems is a supplier of analog component libraries and modeling technology.

Also in June 1988 Mentor Graphics, Apollo Computer, and LSI Logic Corporation (Milpitas, CA) announced an agreement to link LSI Logic's Modular Design Environment software toolset and Mentor Graphics' IDEA Series design tools on Apollo workstations.

Also in June 1988 the company announced an agreement with Minc Inc. (Colorado Springs, CO) to incorporate Minc's universal programmable logic device synthesis tool into Mentor Graphics' board design and simulation environment.

In September 1988 Mentor Graphics and EEsof, Inc. (Westlake Village, CA) announced a cooperative marketing agreement under which EEsof will market its microwave CAE design tools on the Mentor Graphics workstation platform and offer its interface to the Mentor Graphics EDA environment.

e. Future Directions

Anticipating a maturing CAE market, Mentor Graphics is moving into other electronic design tools that the company feels will enjoy high growth rates: PCB layout systems, electronic CAP, packaging, CAT, CAEP, and CASE.

8. PRIME COMPUTER, INC. (Prime Park, Natick, Massachusetts, 01760)
COMPUTERVISION DIVISION (100 Crosby Drive, Bedford, Massachusetts, 01730)

a. Products/Services

Prime Computer, Inc. designs, manufactures, and markets computer systems, workstations, and software—primarily for the end-user market. Prime offers a range of software products for CAD/CAM, FEA, structural analysis, simulation, and facilities design, among other applications. The products are designed for Prime's hardware systems—including 50 Series, PXCL, WS3600, and Prime EXL—and for IBM PCs and compatibles.

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The Computervision Division designs, manufactures, and markets computer-based interactive graphics systems for CAE/CAD/CAM and product data applications. Computervision has developed several integrated lines of CAE/CAD/CAM systems marketed under the names of CADDStation, CDS 4000, Designer, Medusa, and Personal Systems.

b. Markets Served

Prime focuses on a few markets—including discrete manufacturing, where the company's products are used for CAE/CAD/CAM—and also banking and financial services, government, and education. The Computervision Division has focused on five major industry groups: automotive, aerospace, mechanical machinery, electrical/electronic, and AEC.

c. Company Strategy

Prime's thrust lies in evolving beyond its current role as a general-purpose minicomputer vendor to become a provider of integrated system solutions for the manufacturing, commercial, and technical markets. Prime's acquisition of Computervision marks an important step in this direction. Prime is likely to acquire other companies specializing in the engineering and manufacturing area.

d. Recent Activities

In January 1988 Prime acquired Computervision Corporation, as discussed in the Introduction section.

In March 1988 Prime introduced a low-cost series of desktop workstations for manufacturing professionals. The new systems comprise Computervision Division's Professional Series CADDStation product family.

In April 1988 Prime introduced PrimeCONTROL, engineering management software for organizing and controlling large, distributed engineering design data bases.

Also in 1988 Prime introduced PrimeDESIGN, three-dimensional design modeling software that enables engineers to produce solid models of prototype products based on a single data base.

In October 1988 Prime made an initial offer to acquire Calma Company and in early 1989 completed the acquisition. (See Calma Company vendor profile.)

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e. Future Directions

The acquisition of Computervision enables Prime to realize synergies due to numerous similarities. Both companies specialize in the CAD/CAM area, both offer CAD/CAM software that runs on Sun workstations, and both sell a version of Medusa, a software product that was originally developed by Cambridge Interactive Systems, Ltd. (Cambridge, U.K.).

The primary challenge facing Prime is to eliminate product line overlap, particularly with respect to Medusa, and to position its products (Prime and Computervision) so that they complement rather than compete.

9. SCHLUMBERGER TECHNOLOGIES, CAD/CAM DIVISION

(4241 Plymouth Road, Ann Arbor, Michigan, 48106-0986)

a. Products/Services

Schlumberger Technologies (Sunnyvale, CA) is one of the business segments of Schlumberger Limited (New York, NY). The CAD/CAM Division (formerly Applicon) offers turnkey systems for CAE/CAD/CAM applications.

Schlumberger CAD/CAM's primary product, Bravo3•, is an integrated CAE/CAD/CAM system that includes applications for mechanical and electomechanical design, analysis, drafting, and manufacturing.

b. Markets Served

Schlumberger CAD/CAM offers computer-aided tools to industries whose products are mechanical, electronic, or a combination of both. These industries include semiconductors, consumer products, defense, automotive, aerospace, and metals.

c. Company Strategy

Schlumberger CAD/CAM's strategy lies in developing integrated CAD/CAM solutions. The division's chief, Bruce McCann, stated in an interview (*Industry Week*, September 5, 1988), "As sophisticated users come back and buy their second-, third-, or fourth-generation systems, they see the value of having all the applications they need play together in a tightly integrated form. Buyers who once did not perceive the advantages of integration are finding out just how important CAD/CAM integration can be in their business strategy."

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d. Recent Activities

In June 1988 Schlumberger CAD/CAM announced availability of the full line of Bravo3 CAE/CAD/CAM applications on DEC's VAXstation™ series of graphics workstations.

In September 1988, at the International Machine Tool Show held in Chicago, Schlumberger CAD/CAM introduced two new products, Bravo3 NC and Bravo3 CMM. The two products are designed to streamline programming for numerical control (NC) and coordinate measuring machine (CMM) tools.

e. Future Directions

Schlumberger CAD/CAM has ported its software product line to run on engineering workstations. The company plans to refocus on software while using industry-standard platforms for hardware.

10. VALID LOGIC SOLUTIONS, INC. (2820 Orchard Parkway, San Jose, California, 95134)

a. Products/Services

Valid Logic Solutions, Inc. designs, manufactures, and markets turnkey CAE applications for electronic systems design and integrated circuits design.

b. Markets Served

The market for Valid's products consists of two groups of electrical engineers: systems engineers and integrated circuit designers. Valid has sold its systems to customers in the computer, semiconductor, telecommunications, instrumentation, aerospace, and military industries.

c. Company Strategy

Valid's development efforts have been centered around industry-standard platforms. Valid will strive to become a leading supplier of design-to-test systems, hoping to achieve leadership by product development and alliances with or acquisitions of other CAE companies.

d. Recent Activities

In April 1988 Valid acquired Calma's integrated-circuit CAD business. In September 1988 Valid introduced the first phase of consolidation between the Calma line and the company's own line of products.

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In June 1988 Valid announced ADvantage™, an analog design environment for designers with little or no CAD experience.

In October 1988 Valid introduced two new design-to-test products. The Design For Accessibility™ analyzer enables companies to automatically meet test requirements during the PCB layout process. RapidTEST™ is a high-speed concurrent fault simulator that allows design and test engineers to develop test programs and measure test program quality.

Also in October 1988 Valid announced that it had signed a definitive agreement to acquire Integrated Measurement Systems, Inc. (Beaverton, OR). Integrated Measurement Systems is a developer of ASIC (application-specific integrated circuit) device verification products.

Also in October 1988 Valid and Test Systems Strategies, Inc. (Beaverton, OR) announced a joint marketing agreement linking Valid's electronic design automation products with Test Systems Strategies' Test Development Series™ software system. Valid would promote Test Development Series as its recommended solution for bridging the gap between design tools and production automatic test equipment.

In November 1988 Valid announced two new PCB products, Allegro-Review™ and Allegro-Prep™; both are configurations of its Allegro™ PCB Design System tailored for engineers and board designers who require specific PCB tools, but do not require the functionality of a complete PCB system.

e. Future Directions

Valid is on the upswing. After losing $25.9 million on revenues of $66.5 million in fiscal 1987, the company has returned to profitability. Valid anticipates $165 million in revenues and $17.5 million in profits in fiscal 1989. Valid's thrust lies in offering UNIX-based Sun platforms and MicroVAX-based platforms featuring CAE and PCB capability with software links into manufacturing and testing.

11. Other Vendor Activity

IBM's primary CAD/CAM product, CADAM (developed by CADAM division of Lockheed Corporation, Calabasas, CA), runs on the company's mainframes and is a series of products for mechanical design, schematics, facilities planning, and graphics documentation. In June 1988 IBM announced three new CADAM products:

- CADAM Access allows CADAM customers to write their own applications to interact with CADAM data.

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- CADAM AEC Design Base is for industries engaged in the design and construction of complex industrial plants and manufacturing facilities.

- CADAM Drawing Compare compares two drawings, detects and displays their differences, and helps reduce the need for manual inspection of overlaid plots.

In September 1988 Claris Corp. (Mountain View, CA), a subsidiary of Apple Computer, unveiled its CAD software product, Claris CAD. Claris CAD is a low-end CAD product that the company feels will not compete with high-end products like Autodesk's AutoCAD.

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IV New Opportunities

A Introduction

Although there are numerous opportunities in the engineering and scientific market, vendors have not fully addressed the needs of the marketplace. As users increasingly began to demand and use products based on industry standards, vendors that offered proprietary systems in the expectation of locking-in their customers lost market share to companies that did offer standardized products. Today, almost all vendors have joined the industry standards bandwagon and now trumpet their products' conformance to these standards.

The initial buyers in the engineering and scientific market were users of standalone products such as CAD software, where users could easily evaluate costs versus benefits. Users now seek a broader range of integrated applications, including software that can be ported across industry platforms and tied into the corporate data base. The strategies that vendors can use to broaden their product offering include shared product development, marketing alliances, and acquisitions.

In the future, current capabilities offered on minicomputers will be available on workstations and PCs, as these become the preferred hardware platforms. The implications are lower prices, greater unit sales, and potentially declining revenues for some vendors. However, the offering of greater capabilities on lower-priced systems will serve to overcome a threshold level in the market by opening the market to new users and new applications.

B Mechanical Engineering

There are three major areas of opportunity in the CAD market for mechanical engineering applications: three-dimensional capabilities, integration, and solid modeling.

Three-dimensional modeling and design represent a significant opportunity. Applications include 3-D mechanical design, fluid and air flow, and modeling of molecules in three dimensions.

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The next major opportunity in the market is the emergence of genuine integration of CAD and CAM, and linkages between CAE and computer-aided testing—developments that promise to compress the process of design, testing, and manufacturing.

Integration is important because it streamlines the product development cycle. A circuit board, for example, evolves from a schematic design into a layout of physical parts and is then rendered as an assembly drawing and transferred to manufacturing. At the same time, the board's mechanical housing must be designed and fitted. With an integrated data base, this activity becomes a single flow of information since all of these functions share a common data base. Thus, engineers at each step can work from the same model, speeding the communication of the design progress and automatically ensuring parts accuracy and compatibility.

Costly R&D efforts will be required to succeed in developing and bringing such products to market.

Solid modeling software is an application that is expected to dominate design applications by the end of the decade. In the past, the computing power needed for solid modeling was often prohibitive, but as hardware prices declined and processing power increased, the capabilities of solid modeling became available to more engineers. Solid modeling software enables designers to describe the volume and mass of mechanical parts on the computer—a considerable improvement over the edges and corners provided by other kinds of CAD software.

C

Electrical/Electronic Engineering

The opportunities in the CAD/CAE market for electrical applications revolve around price, improved data management, and performance.

A drawback to CAD/CAE systems is price. What is needed are systems in the $10,000-$20,000 price range with the same performance and functionality as the systems that average about $50,000. Such systems will be in a price range that many more users can afford. There appears to be a threshold at about $20,000 where large companies think of buying a workstation for every engineer.

One of the problems associated with CAD/CAE systems is the lack of sophisticated data management. Most systems have only limited facilities for relating information files. Once a hierarchical data base management system can be integrated into a workstation, the designer will be relieved of much routine work, with a key benefit being the ability to do modular design.

Another need felt by chip designers is for faster design simulation.

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D

Civil Engineering	Speed is the commodity FEA deals in. FEA compacts the time it takes to test designs. However, the computational requirements are enormous, necessitating high-speed computers. Vendors should take advantage of improvements in hardware performance and offer systems that will guide engineers from the beginning or conceptual phase of the design process and help them find new designs.

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Appendix: Forecast Data Base

This appendix contains the following forecast information, as shown in Exhibit ES-A-1.

- Market size by delivery mode for each year, 1987-1993
- Market growth rates for 1987-1988
- Compound annual growth rate (CAGR) for each delivery mode for the five year period 1988-1993.

EXHIBIT A-1

ENGINEERING AND SCIENTIFIC CROSS-INDUSTRY SECTOR USER EXPENDITURE FORECAST BY DELIVERY MODE 1988-1993 ($Millions)

Sector by Delivery Mode	1987	Growth 87-88 (%)	1988	1989	1990	1991	1992	1993	CAGR 88-93 (%)
Total Engineering & Scientific Sector	730	16	845	990	1,155	1,350	1,600	1,910	18
Processing Network Services	110	3	115	120	130	130	140	140	4
Application Software Products	310	28	400	500	615	770	970	1,230	25
Mainframe	90	14	110	120	130	150	170	190	12
Minicomputer	130	25	160	200	240	290	350	430	22
Workstation/PC	90	48	130	180	245	330	450	610	36
Turnkey Systems	310	7	330	370	410	450	490	540	10

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Appendix: Forecast Reconciliation

This appendix contains the following information:

- Exhibit ES-B-1 which indicates the changes made in this year's forecast compared to last year's
- An explanation of any significant changes that were made to the forecasts

INPUT has significantly down-sized the processing services market based on an analysis of the major vendors in this area. Processing services vendors include Boeing Computer Services, Computer Power, and Martin Marietta Data Systems, companies that have large computer installations. INPUT feels the lower estimate more accurately reflects the market.

INPUT has raised the estimate for workstation/PC applications software and lowered the growth rate for mainframe applications software due to the acceptance and rapid growth of PCs and workstations as the preferred hardware platforms for engineering and scientific applications.

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EXHIBIT B-1

ENGINEERING AND SCIENTIFIC CROSS-INDUSTRY SECTOR DATA BASE RECONCILIATION OF MARKET FORECAST BY DELIVERY MODE ($Millions)

Industry Sector	1987 Market			1992 Market			CAGR 87-92	CAGR 87-92
	1987 Forecast	1988 Forecast	Variance (%)	1987 Forecast	1988 Forecast	Variance (%)	1987 Forecast (%)	1988 Forecast (%)
Total Engineering and Scientific Sector	900	730	23	1,760	1,600	10	14	17
Processing/Network Services	260	110	136	340	140	143	6	5
Application Software Products	290	310	-6	910	970	-6	26	26
Turnkey Systems	350	310	13	510	490	4	8	10

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About INPUT

INPUT provides planning information, analysis, and recommendations to managers and executives in the information processing industries. Through market research, technology forecasting, and competitive analysis, INPUT supports client management in making informed decisions.

Continuous-information advisory services, proprietary research/consulting, merger/acquisition assistance, and multiclient studies are provided to users and vendors of information systems and services (software, processing services, turnkey systems, systems integration, professional services, communications, systems/software maintenance and support).

Many of INPUT's professional staff members have more than 20 years' experience in their areas of specialization. Most have held senior management positions in operations, marketing, or planning. This expertise enables INPUT to supply practical solutions to complex business problems.

Formed as a privately held corporation in 1974, INPUT has become a leading international research and consulting firm. Clients include more than 100 of the world's largest and most technically advanced companies.

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